Hydrometeorological Characteristics of Rain-on-Snow Events Associated with Atmospheric Rivers

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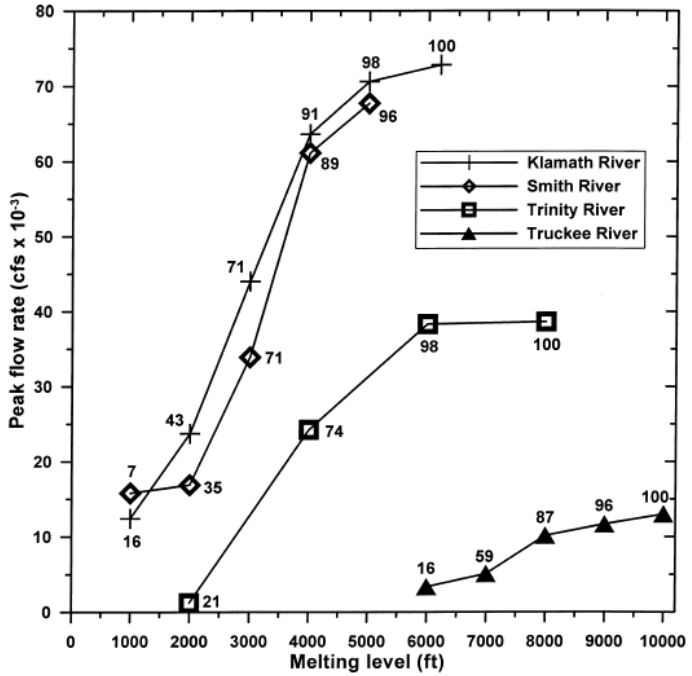
Rain-on-snow (ROS) events present enhanced flood risks (rainfall+snowmelt)

- Rössler et al. (2014): an event in Bernese Alps, Switzerland reduced snow depth by 40–60 cm at 3 meteorological stations within 6 hours
- Marks et al. (1998): an event in the Pacific Northwest melted 35–100% of the snowpack on the western slope of the northern and central Cascades

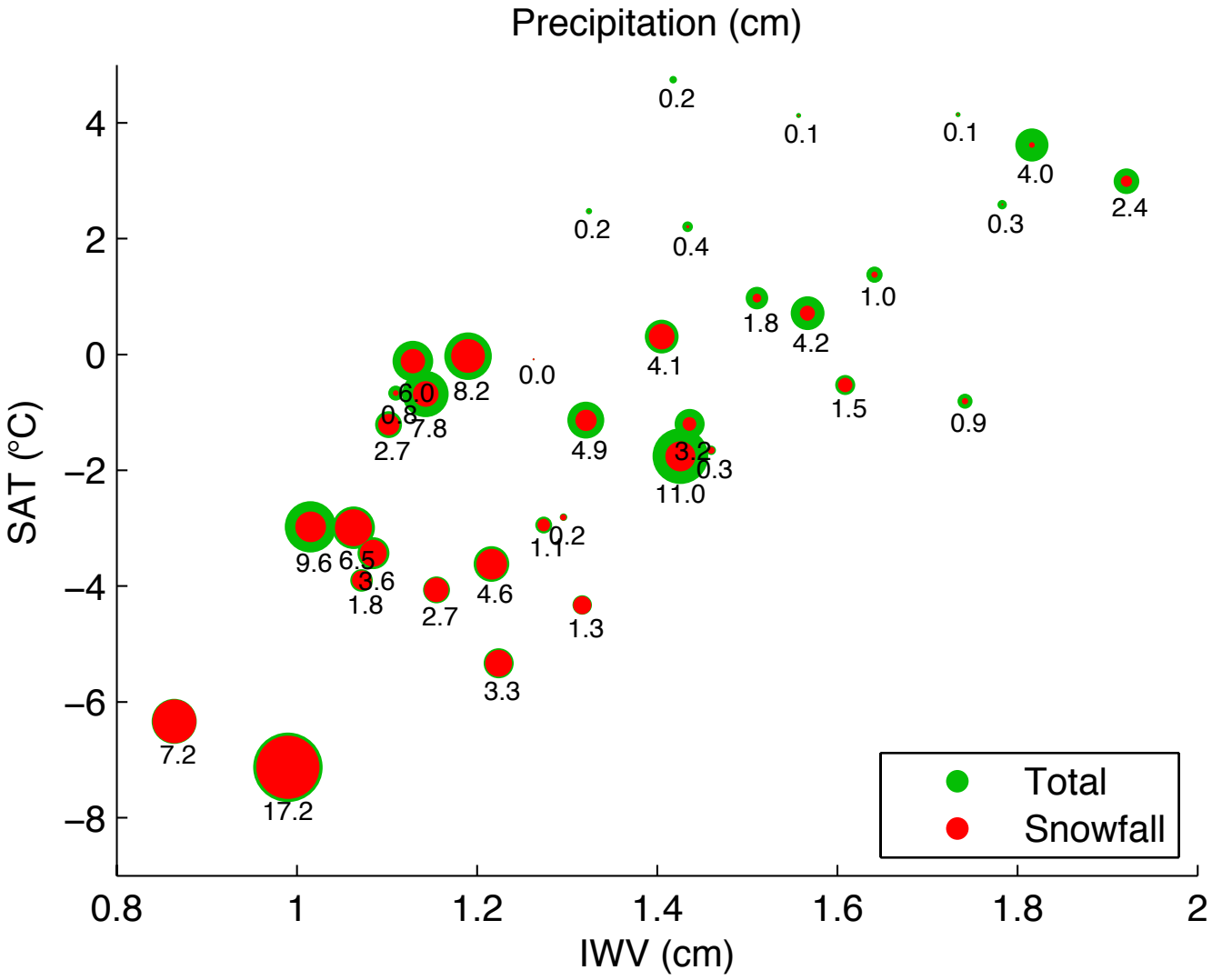
Atmospheric river (AR) storms are typically warmer, with higher melting levels than other storms

Kim et al. (2013)	NSN	SSN
	ERA-Interim	ERA-Interim
AR wet days	2,746 m (87)	2,949 m (60)
Non-AR wet days	2,332 m (792)	2,428 m (603)
Differences	414 m	521 m



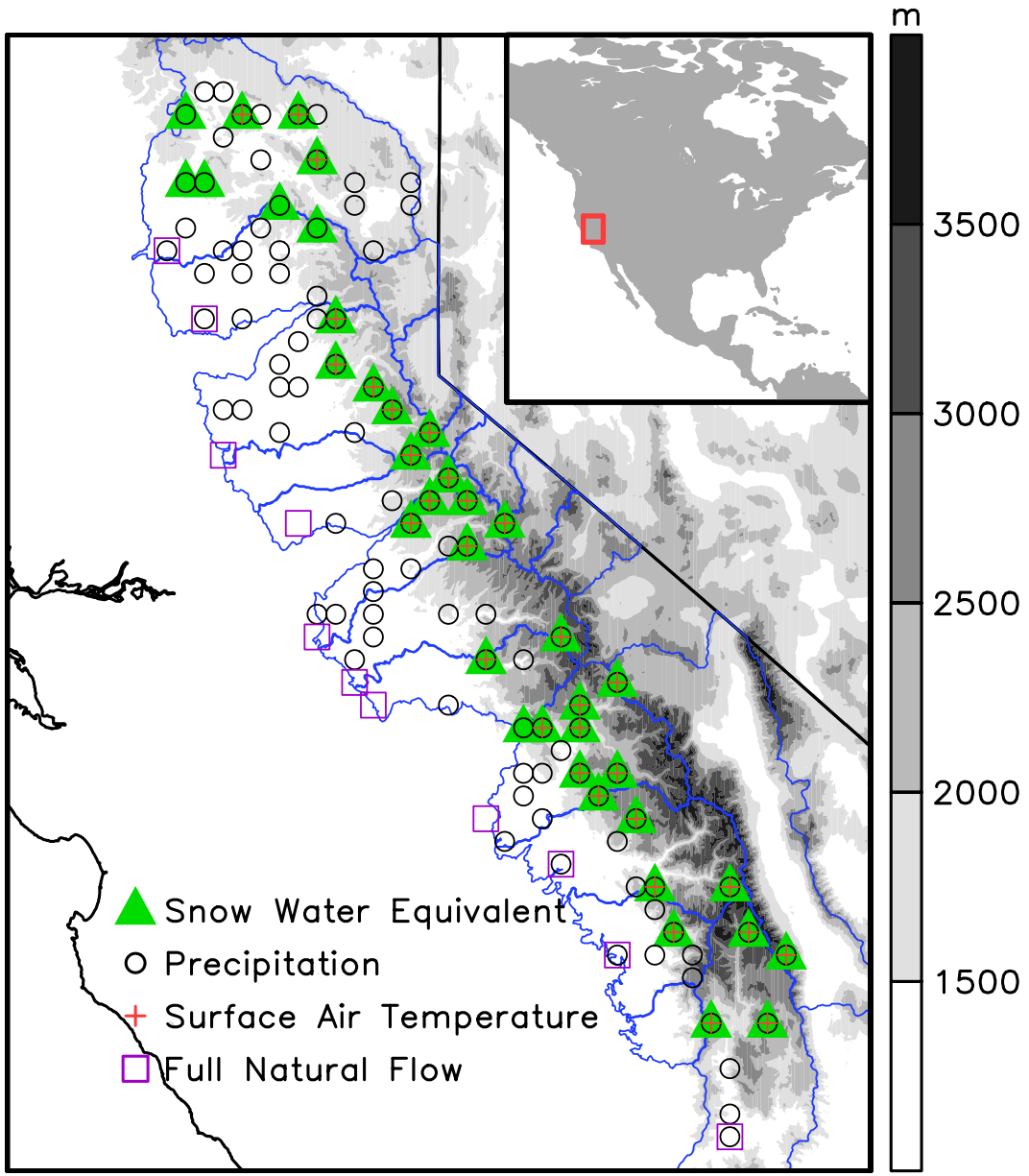
600 m rise → 3x runoff
White et al. (2002)

AR rain/snow ratio is sensitive to temperature



Guan et al. (2010)

Data Sources and ROS Definition



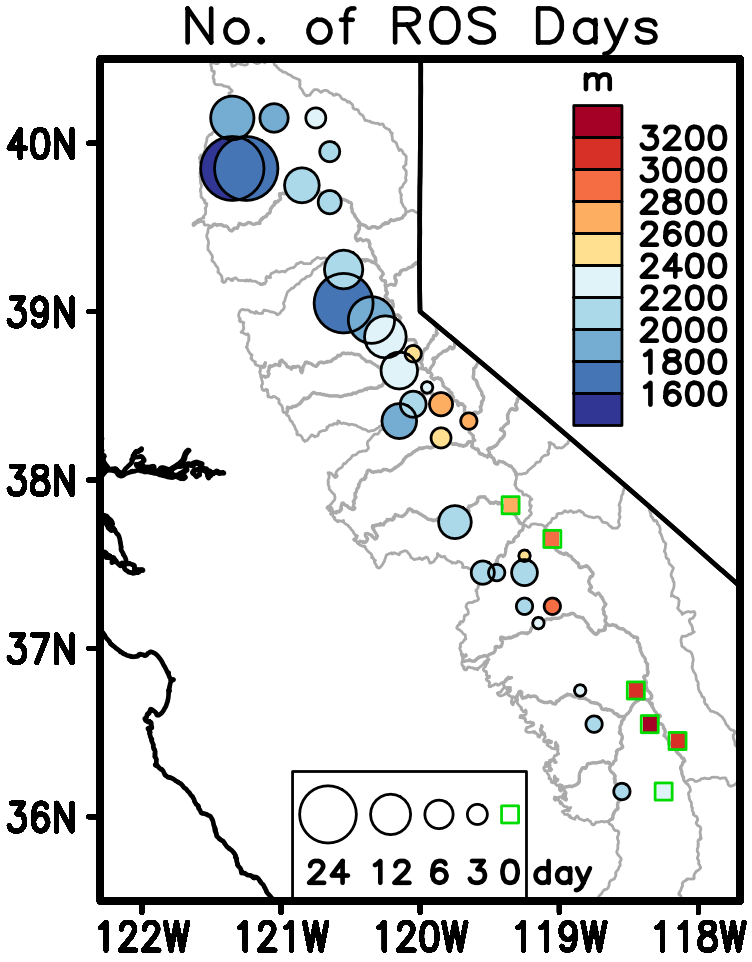
ROS station:

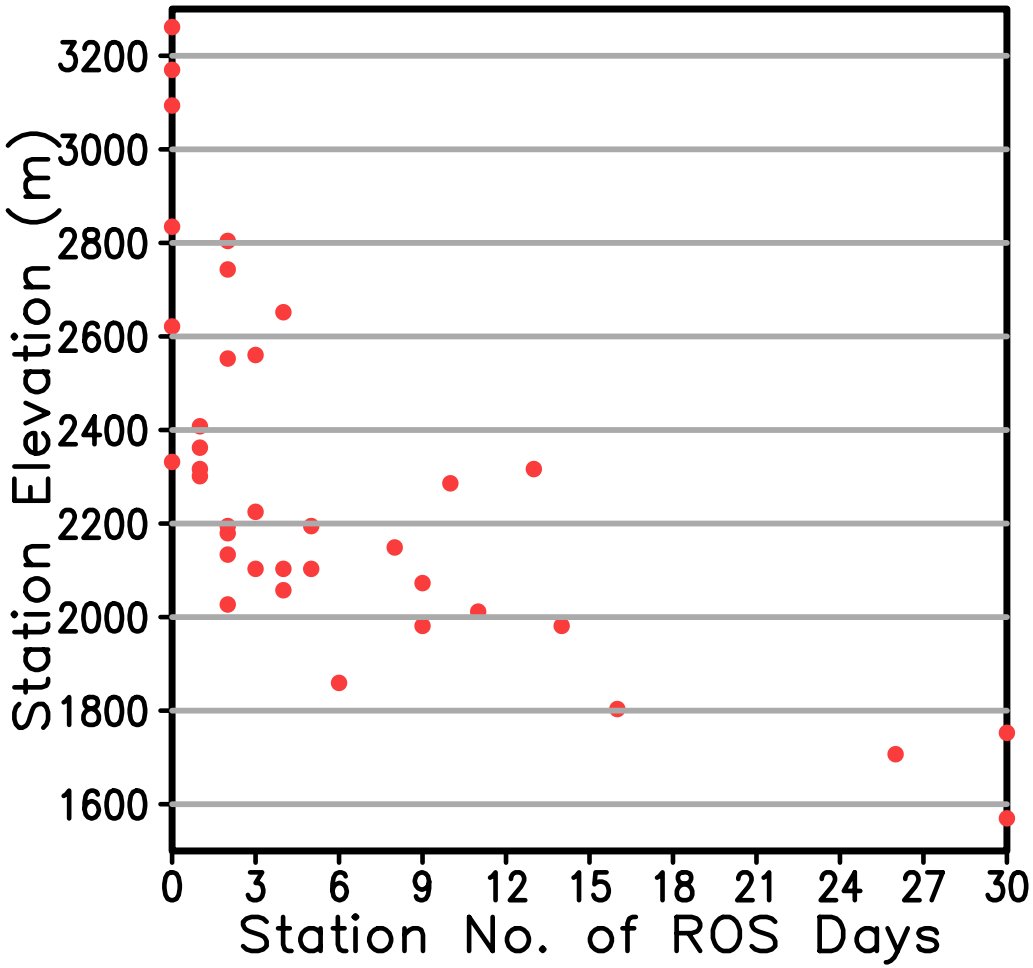
- Precip. >1 cm/day
- ΔSWE <0

ROS date:

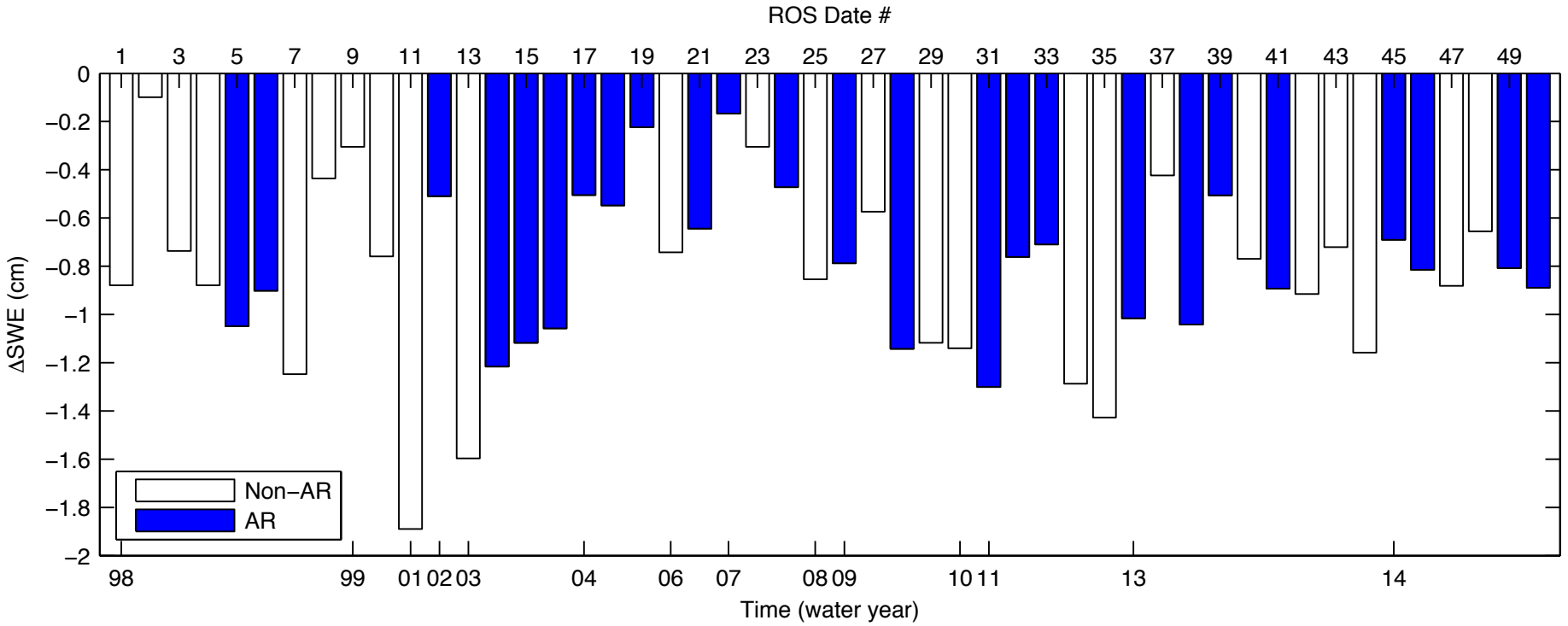
- 3 or more ROS stations
- within any 200 km zonal band

Rain-on-snow occurrence is elevation-dependent; more at lower elevations

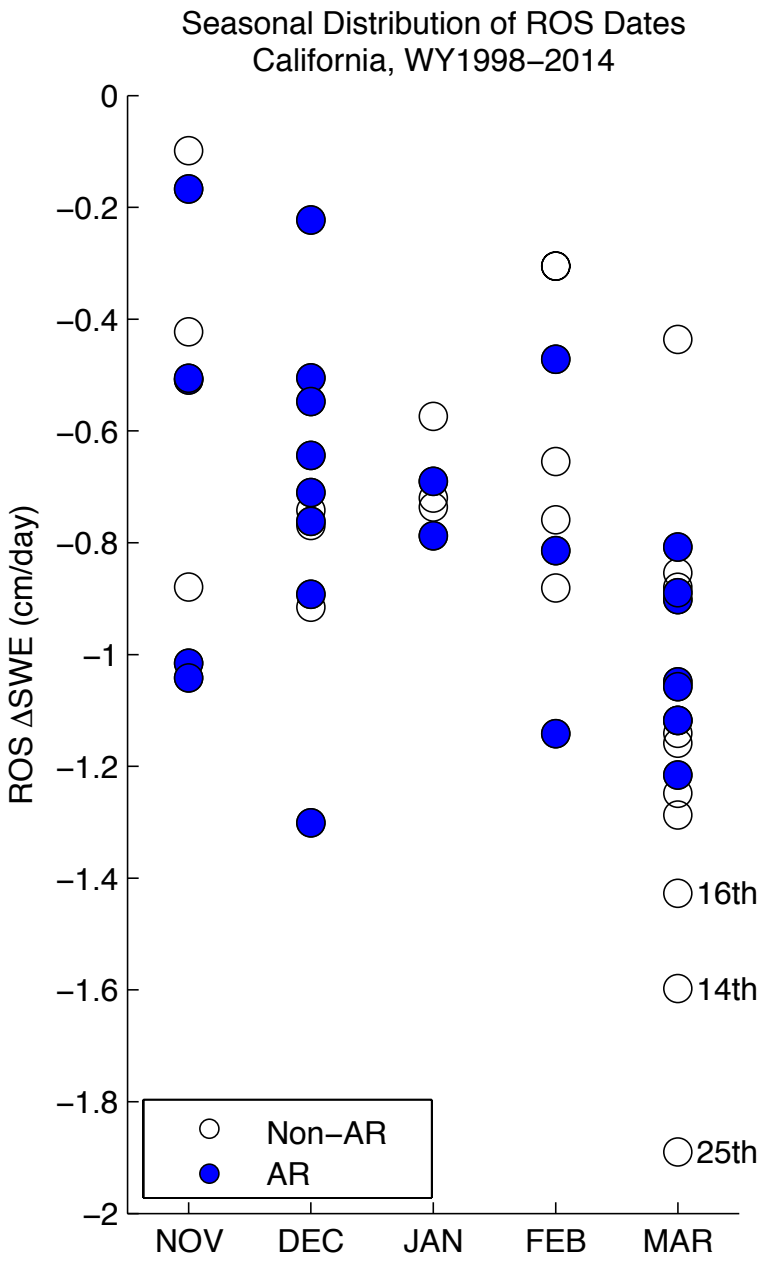


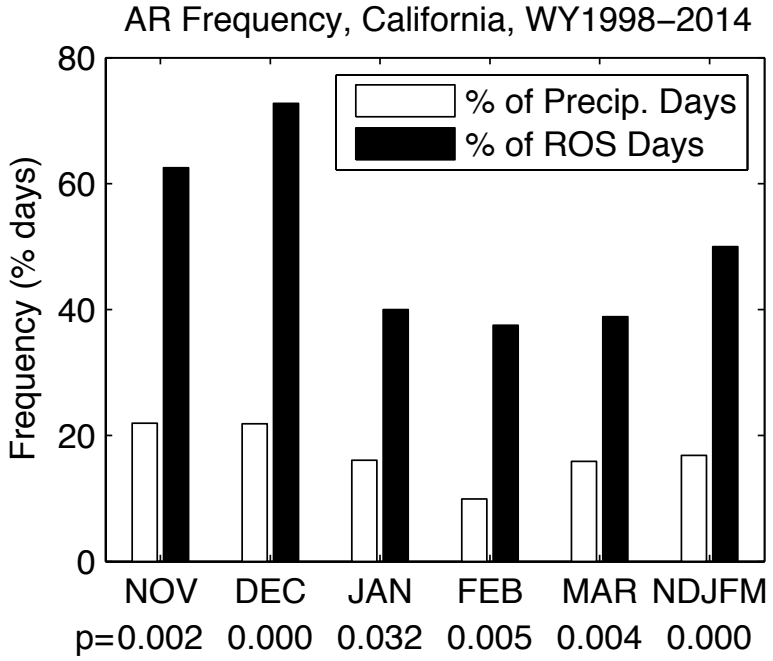


50% of ROS dates are also AR dates



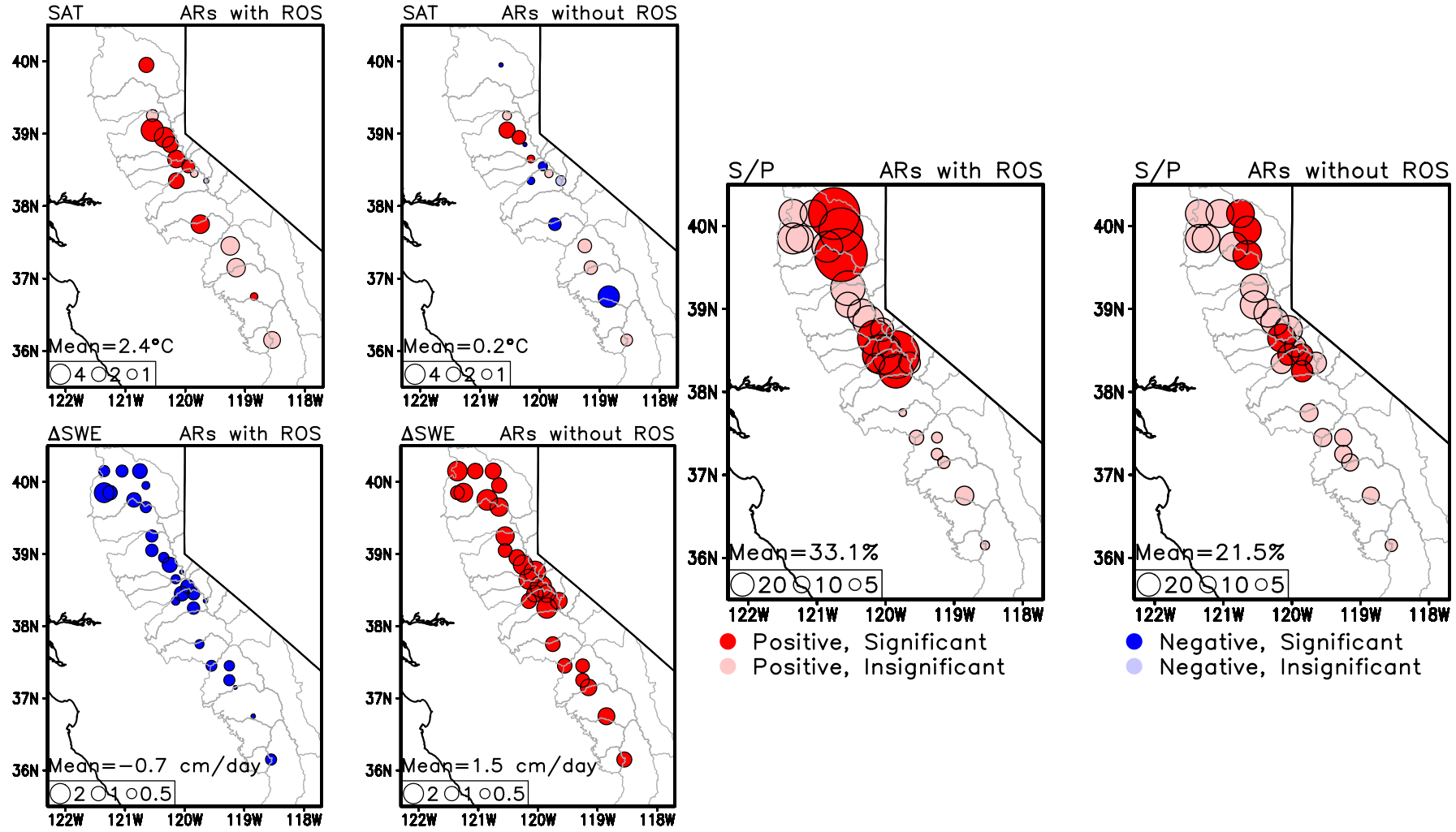
ROS occurs throughout the winter season, with strong connection to ARs





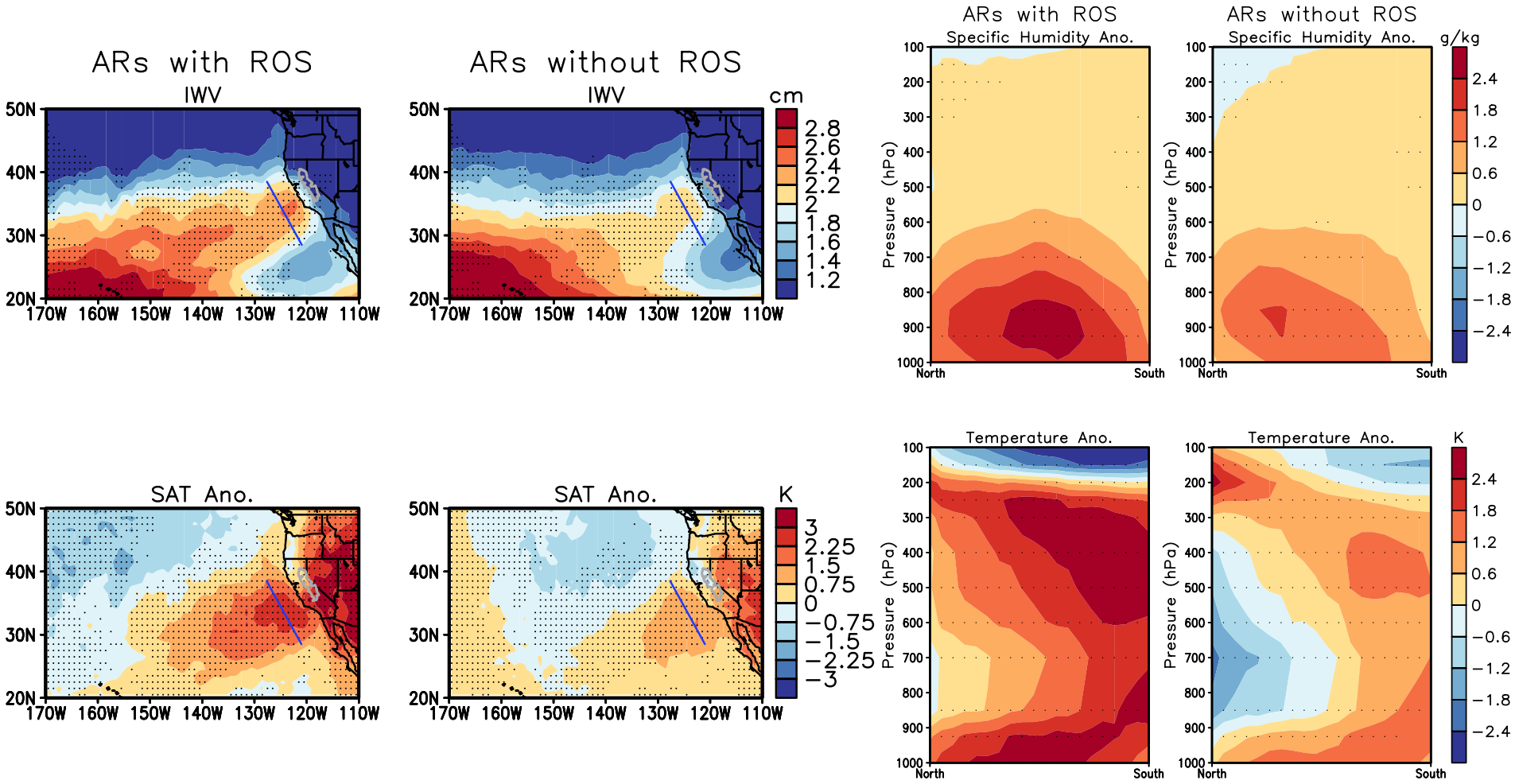
- March has the most monthly ROS occurrence, followed by December
- In any month, the proportion of ARs in ROS days is significantly higher than the general AR frequency in precipitation days

ROS vs. Non-ROS ARs: Overland Characteristics



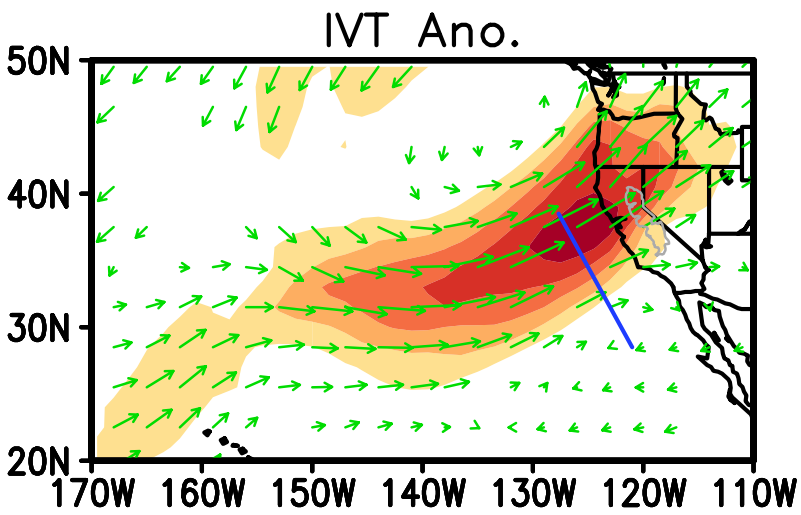
- ARs with ROS are significantly warmer; daily reduction in SWE is about half the mean accumulation rate
- Streamflow/precip. ratio is about 50% higher during ARs with ROS

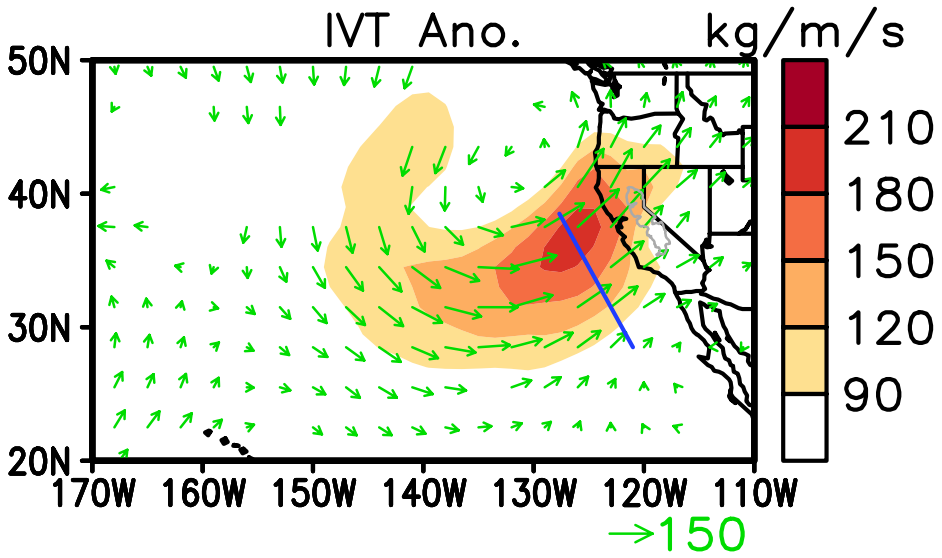
ROS vs. Non-ROS ARs: Offshore Characteristics



AIRS retrievals reveal distinct offshore characteristics of ARs with vs. without ROS

ROS vs. Non-ROS ARs: Offshore Characteristics





IVT anomalies typically directed from the tropics/ subtropics in ARs with ROS

Summary

- 50% of ROS events in the Sierra Nevada are associated with ARs
- Compared to ARs without ROS, ARs with ROS are on average warmer by ~2 K and with ~50% higher streamflow/precipitation ratios (thus enhanced flood risk)
- ARs with ROS are typically associated with IVT anomalies directed from the tropics/subtropics
- The results highlight the potential value of observing these events for snow, rain, and flood prediction

Guan, B., D. E. Waliser, F. M. Ralph, E. J. Fetzer, and P. J. Neiman (2016), Hydrometeorological characteristics of rain-on-snow events associated with atmospheric rivers, Geophys. Res. Lett., 43, doi:10.1002/2016GL067978.